technical note

Structural Tests of Aircraft Window Assembly Equipped with Smoke Evacuation Valve

Anthony Wilson
William Cavage, Jr.

September 1990

DOT/FAA/CT-TN89/44

Document is on file at the Technical Center Library, Atlantic City International Airport, N.J. 08405

U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, N.J. 08405

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/CT-TN89/44		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code / 8. Performing Organization Report No.
STRUCTURAL TESTS OF AIRCRAFT WINDOW ASSEMBLY EQUIPPED WITH SMOKE EVACUATION VALVE	5. Report Date: September 1990 6. Performing Organization Code: 8. Performing Organization Report No.: DOT/FAA/CT-TN89/44
7. Author(s): Anthony Wilson and William Cavage, Jr.	
9. Performing Organization Name and Address Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405	13. Type of Report and Period Covered: Technical Note 14. Sponsoring Agency Code: ACD-240

15. Supplementary Notes

16. Abstract

This report presents the results of three tests performed on a window and window frame of a Boeing 707. The purpose of the test, conducted at the Federal Aviation Administration Technical Center, was to determine the maximum moment the window could withstand before becoming dislodged from its frame due to the failure of the window retention clips. The window assembly was modified to fit into a load machine. The loads were measured with a load cell and recorded on a Honeywell Test Management System.

17. Key Words	18. Distribution Statement
Smoke Evacuation Smoke Evacuation Valve Airplane Window Window Structural Strength	Document is on file at the Technical Center Library, Atlantic City International Airport, New Jersey 08405

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	17	

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized

TABLE OF CONTENTS

LIST OF ILLUSTRATONS

EXECUTIVE SUMMARY

The Federal Aviation Administration is developing a smoke evacuation valve to install in the window of some jet aircraft. When the valve is actuated into the airflow stream, it produces a load on the window which is transferred onto the window retention clips. A window and window frame from a Boeing 707 were tested to determine the maximum moment the window could withstand and also the maximum load that each clip could withstand before failure. The expected failure moment for the window was about 240 inch-pounds, and the expected failure load of each clip was estimated to be 80 pounds.

Three tests were performed to determine the maximum moment and the maximum load. A load machine and a load cell were used to complete the actual loads in each test. The window section was adapted to fit into the load machine, and predetermined loads were applied to each specimen. These tests determined that a window could take a normal force of 2100 pounds before failure.

INTRODUCTION

Testing of a smoke evacuation valve was conducted at the Federal Aviation Administration (FAA) Technical Center in support of the FAA's Fire Safety Program. The objective of the test series was to determine if a prototype smoke evacuation valve and supporting structure could withstand aerodynamic forces that it would experience under actual flight conditions. The smoke evacuation valve was designed to vent smoke from an airplane during flight. Figure 1 shows the smoke evacuation valve which is approximately a 3-inch square that is opened into the airflow stream at a maximum angle of attack of 43 degrees. This creates a low pressure area to draw the smoke out of the airplane. The valve was mounted in an aluminum window blank that fits into the window frame and was held in place by standard window clips. The mounting fixture that holds the window is shown in figure 2. The window is held in place by ten clips, each acting on the window and the frame. Each clip's function is to hold the window in place while the plane is depressurized. When under pressure, the window acts as a self-sealing plug in the window frame. Experience indicates that during flight the force of the air against the extended valve will cause a moment on the window blank, tending to place additional forces on some of the window clips. With the smoke evacuation valve actuated, the plane will not be under pressure and there will be a moment acting on the window.

DESCRIPTION

THEORY.

The first test (figure 3) was designed to simulate the in-flight conditions that were put on the window by pulling on a lever arm which protruded through the window. To obtain a target moment and a moment arm for the test, the center of force was found first. The force of a fluid flowing over a body acts at the center of gravity. The maximum force on the valve will be obtained when the valve is at maximum deflection. The center of load on the valve is therefore determined by the following:

$$\text{Center of Load} = 1/2\ \ell \sin 43^{\circ} \text{ in inches}$$

(with ℓ = length of valve door = 3 inches)

which equals approximately 1 inch. A target load was obtained by the equation for drag, using the coefficient of drag (C_d) of a flat plate letting S denote the plate area and using a speed of 500 feet per second (ft/s). The equation of drag is as follows:

$$D = 1/2\ \rho V^2 C_d S$$

(with ρ =0.002377 SLUG/ft^3,S=0.0625ft^2,C_d,=1.5, and V=500ft/s)

A drag value of approximately 30 pounds was calculated. Based on a safety factor of five, the experimental load for the smoke evacuation door was computed to be 150 pounds. Utilizing these two values, it can be calculated that the target moment for the window was approximately 150 inch-pounds.

TEST SPECIMAN.

After finding the center of force of the smoke evacuation door, the horizontal distance of travel across the window to the center of force was measured. At that point in the Plexiglass™ window, a lever arm was constructed out of a grade six, structural bolt. To prevent the Plexiglass window support from cracking under the load, the window was supported with a 1/8-inch aircraft quality aluminum plate on each side. These plates were fastened flush to the window with soft rivets. The window frame and window, with clips, were then adapted to fit into a tensile/tension machine, Riehle type, model No. F.S.5. To allow for accurate data, the window had to be securely fastened within the load machine frame while the lever arm was pulled.

For the second test (figure 4), a target load for the window clips was estimated by considering the normal force that the window clips would withstand. Since pressurized airplanes have a pressure differential of about 8 pounds per square inch (psi) with a window area of about 100 square inches, there is a force of about 800 pounds on the window frame. Considering that the clips were not loose, it was speculated that the window clips would experience 800 pounds upon depressurization. The window was secured by 10 clips and it is assumed that the load is distributed evenly with each window clip.

The second part of test No. 2 was designed to determine the maximum load that the window clips could withstand while under a normal force. The window frame was modified so that the window could be pulled against the clips, while the window frame remained rigid. To be sure that the load was dispersed evenly about the window, four cables were fastened to the window, evenly spaced from the center. The cables were then hooked to a metal joint, which was pulled on by the tensile machine. The window frame was secured in a similar fashion with four cables meeting at a metal joint which was secured to the tensile machine's base. All cables used were 5/32 inch with cable balls pneumatically swaged on to secure them to the cable. All material used was acceptable aircraft grade material.

The third test (figure 5) was designed to examine the strength of one clip by itself. An empty window frame was modified to fit in the tensile machine. One clip was then fastened to the frame in its usual fashion. A strip of 1/4-inch aircraft quality aluminum was positioned in the window frame to simulate the window. A piece of 3/16-inch cable was fastened to one end of the aluminum strip. The cable was then pulled until the clip failed. The test apparatus is shown in figure 5.

INSTRUMENTATION.

The tensile/tension machine, as shown in figure 6, was used in each test to impose a force on the window. The test setup as used in test No. 2 is shown in figure 7. A load cell was used to measure the forces acting on the window. The output of the load cell was fed into the data acquisition system for storage and analysis as shown in the schematic in figure 8. Both a position transducer and a load cell are used in test No. 3 to measure both deflection and load. Figure 9 shows the computer data acquisition system in the test facility.

SUMMARY OF RESULTS

With the target force being in the neighborhood of 150 to 200 pounds, the test apparatus was designed to take forces in the range of 700 to 1000 pounds. Although our initial plan was to test the window clips to failure, it became impossible in the load range we had established. Figure 10 shows a plot of load versus time for the moment pull test. The specimen was loaded to approximately 700 pounds. At this high load it was observed that the window had not yielded.

Extra reinforcement was adapted to the window frame and a second moment pull test was done. The results of the second moment pull test can be seen in figure 11. In the second moment pull test, the 1.6-inch moment arm was loaded with 1100 pounds and neither the window, clips, nor the window frame yielded, cracked, or broke in any way. The moment of 1760 inch-pounds was well beyond the initial target of 240 inch-pounds.

On the second test it became apparent that the window was quite strong, and a normal pull test (perpendicular) would give a good indication of how much load each clip was capable of carrying. Figure 12 shows a plot of load versus time for the normal pull test. The window was loaded with 1700 pounds. Although the window clips began to bend out slightly, there was no failure in any window structure. Again, with the target force being in the 800-pound range, there was no reason to pull to failure.

The third test was designed to simply show how much force one clip could take when normally loaded. Although the true target load would only be 1/10th of 800, or 80 pounds, to obtain some failure load for the clips it was decided that the clip would be taken to failure regardless. Figure 13 shows a plot of load versus time for the single clip pull test. Figure 14 shows a plot of deflection versus time for the single clip pull test. The rapid increase in deflection at approximately 10 seconds represents the point at which the clip broke. While the simulated window was under a load, the clip began to bend back against itself at 150 pounds and broke at about 205 pounds.

CONCLUSION

The imposed loads during inservice operations on the smoke evacuation valve casing have been experimentally determined to be approximately 30 pounds. The data given here clearly illustrate that a safety factor of five has been completely satisfied. With a moment of 30 inch-pounds (Coeff of drag (30) center of load (1)), the experimental safety factor of five has also been more than satisfied.

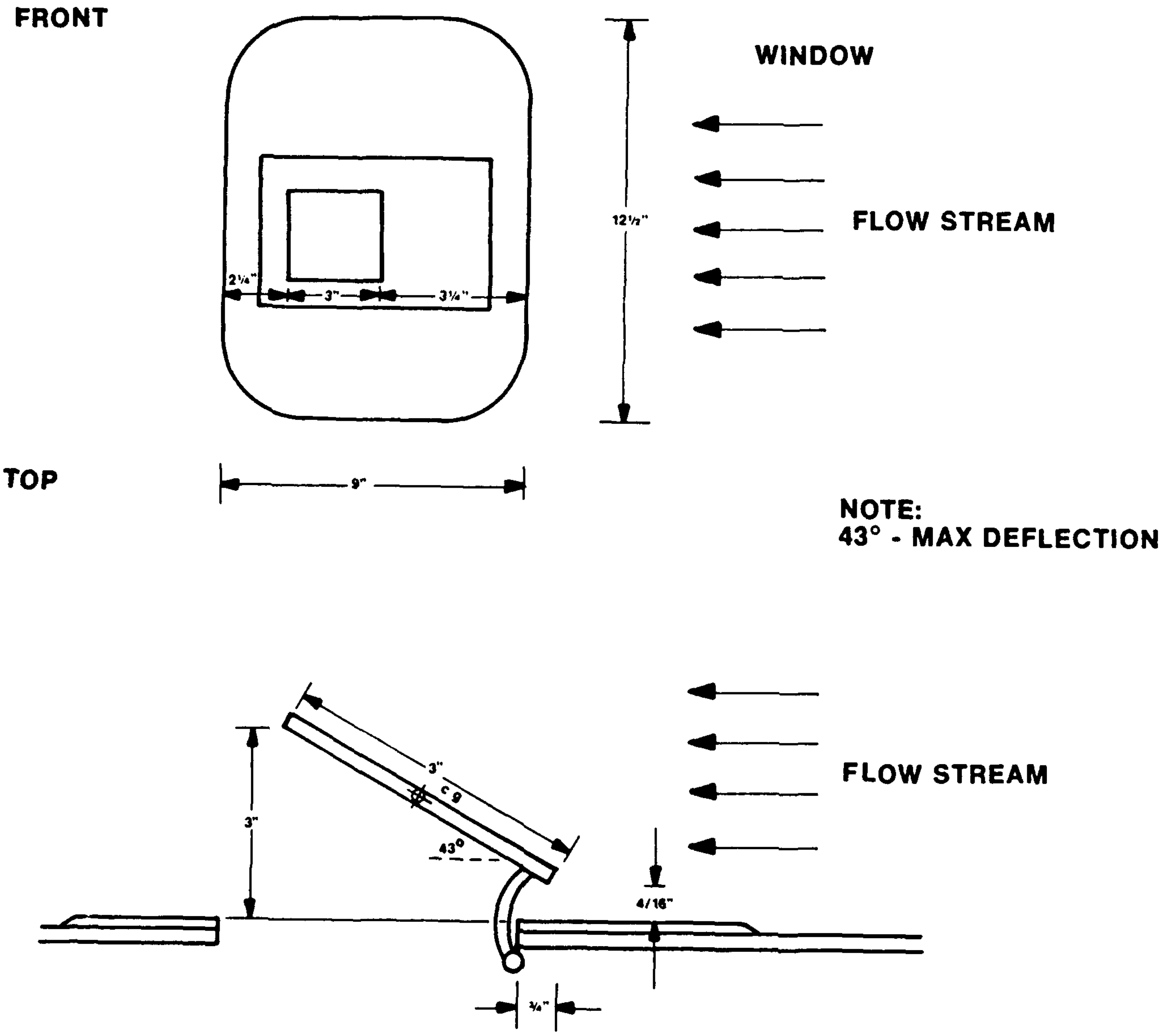

FIGURE 1. SMOKE EVACUATION VALVE

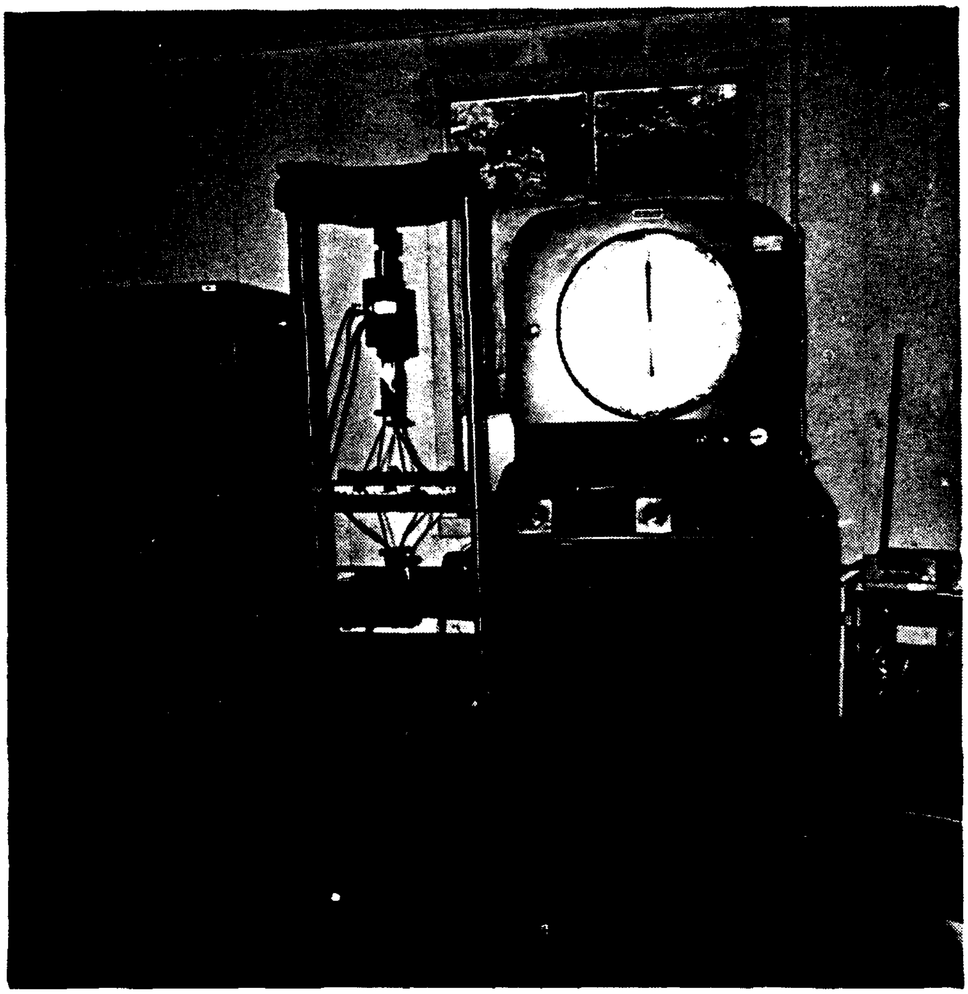

FIGURE 2. NORMAL PULL SPECIMEN WITH WINDOW CLIPS

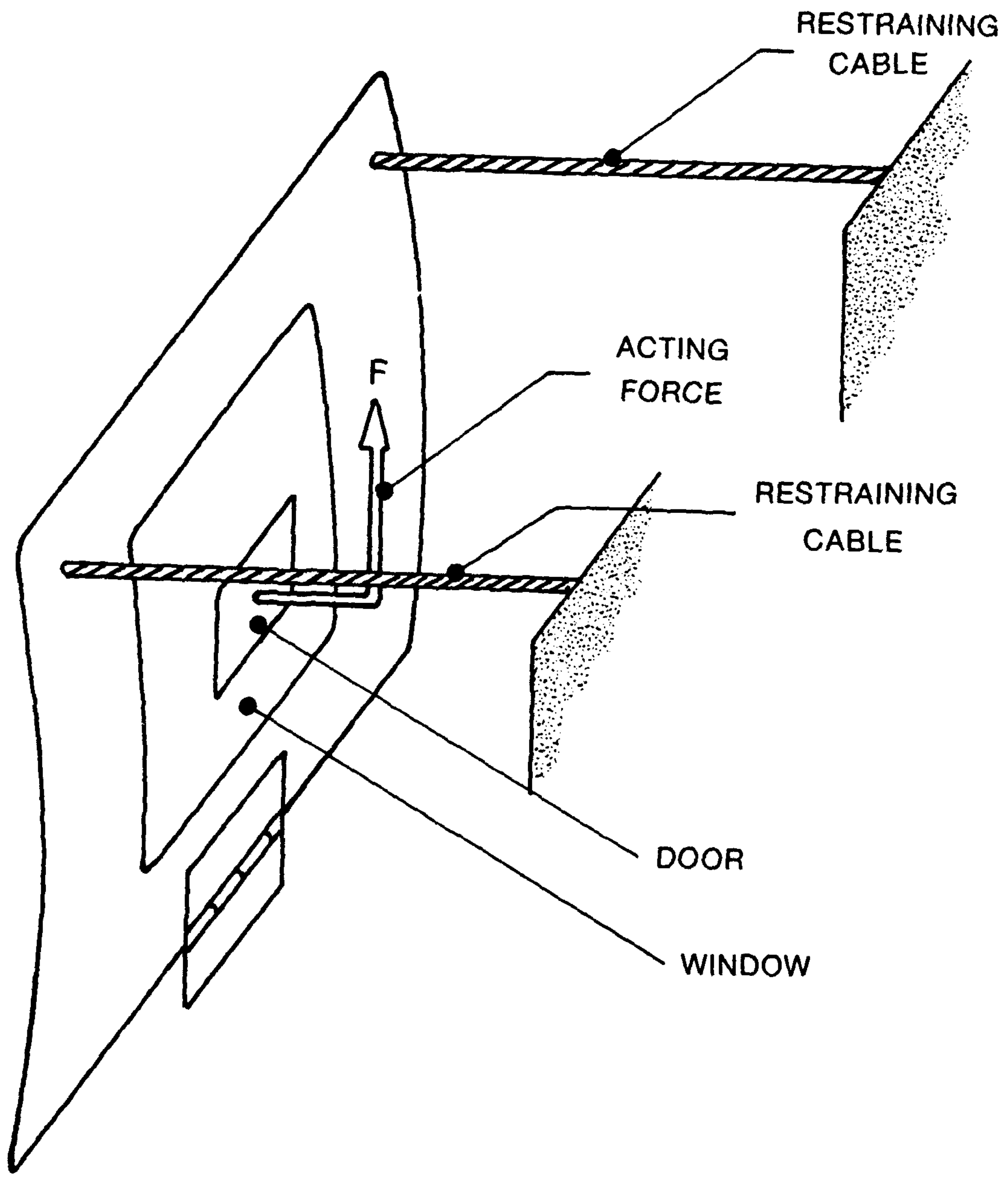

FIGURE 3. TEST NO. 1 MOMENT PULL TEST

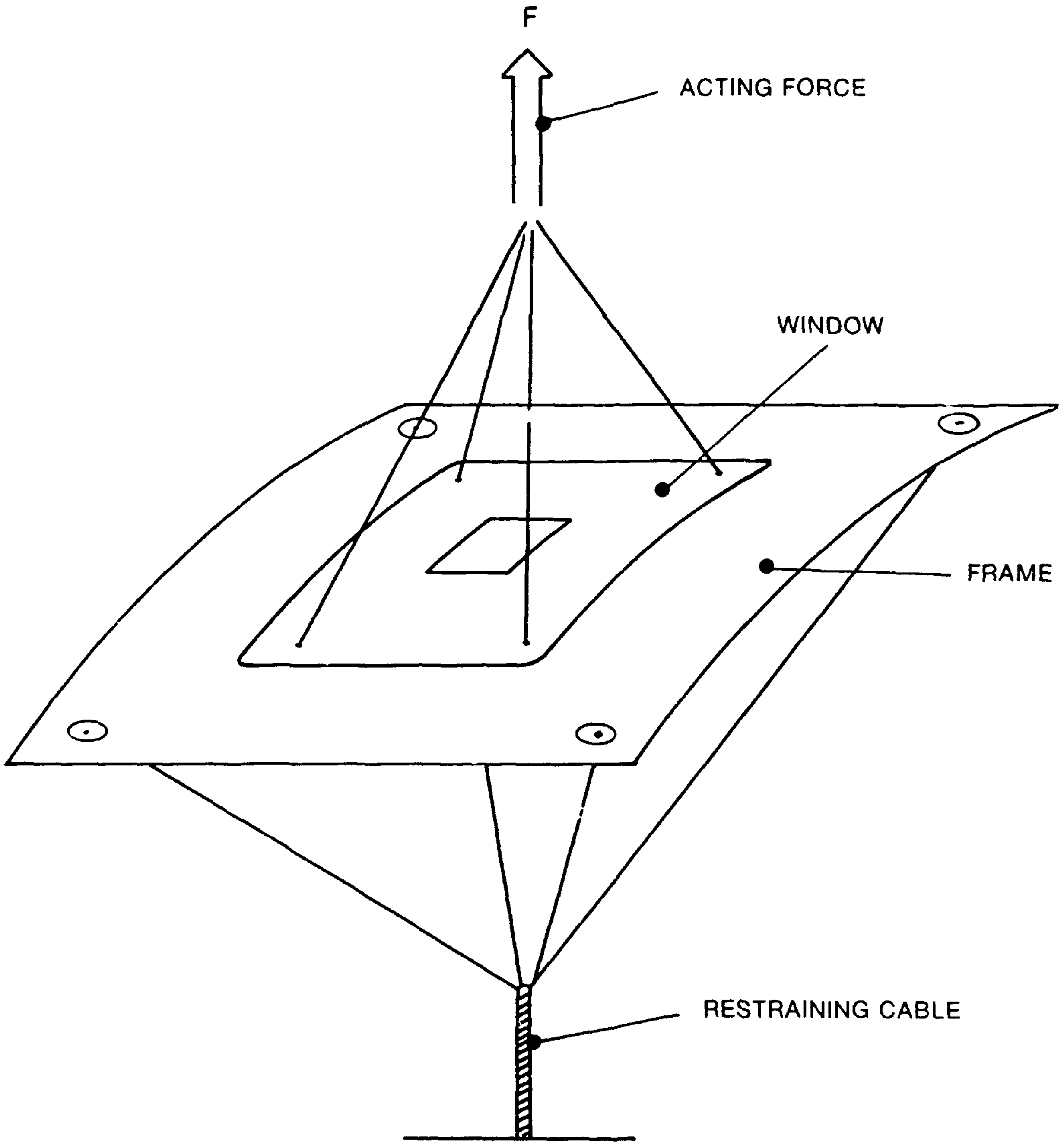

FIGURE 4. TEST NO. 2 NORMAL PULL TEST

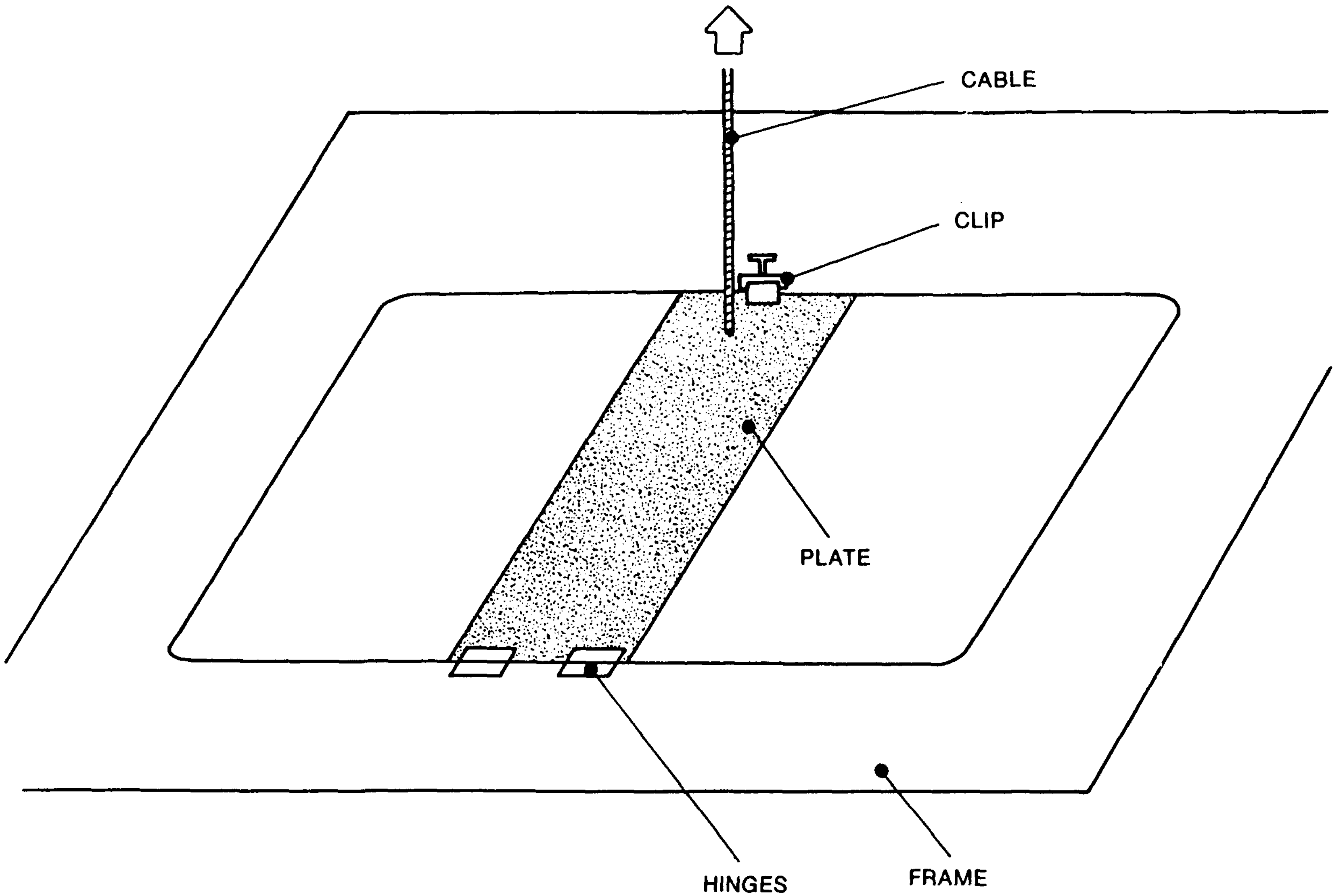

FIGURE 5. TEST NO. 3 SINGLE CLIP PULL

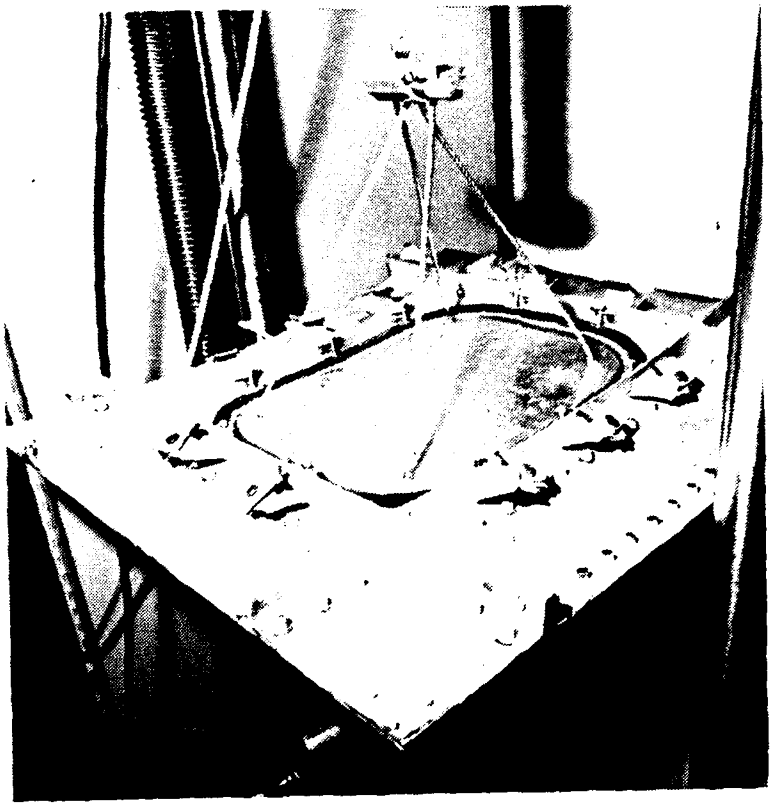

FIGURE 6. RIEHLE TENSILE/TENSION MACHINE MODEL NO. F.S.5

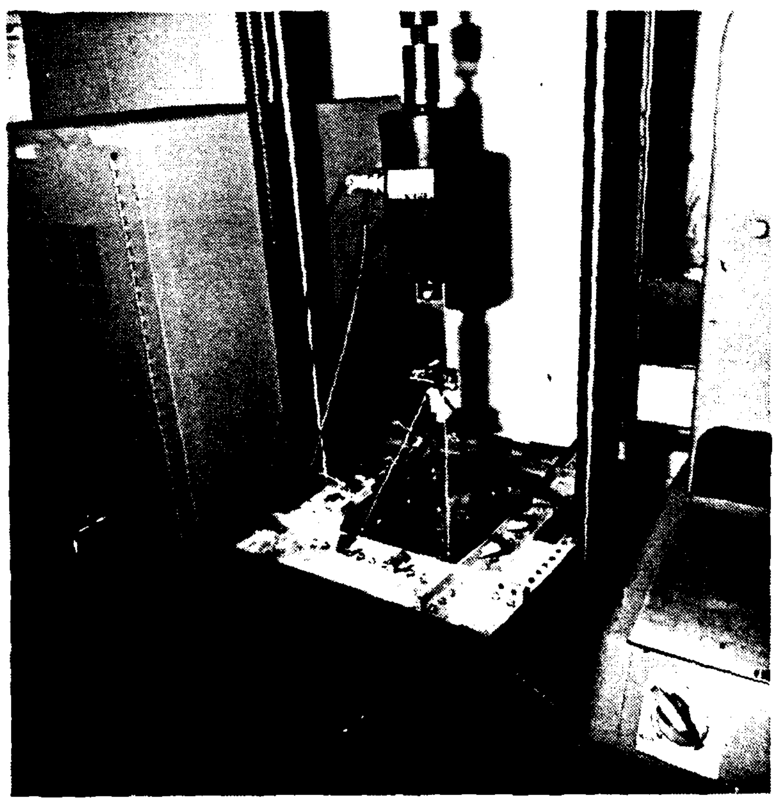

FIGURE 7. NORMAL TEST SPECIMEN AS ADAPTED FOR RIEHLE TENSIL/TENSION MACHINE

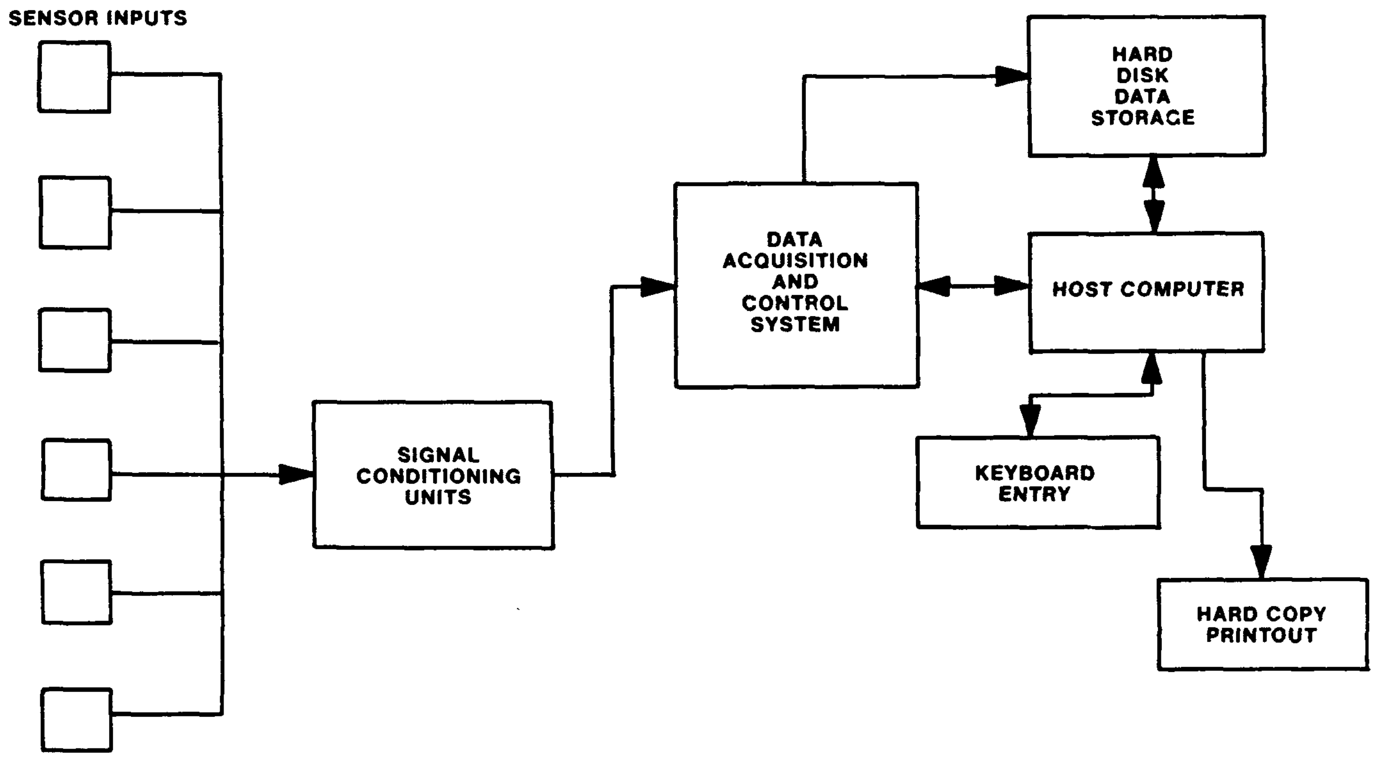

FIGURE 8. INSTRUMENTATION SCHEMATIC

FIGURE 9. DATA ACQUISITION SYSTEM

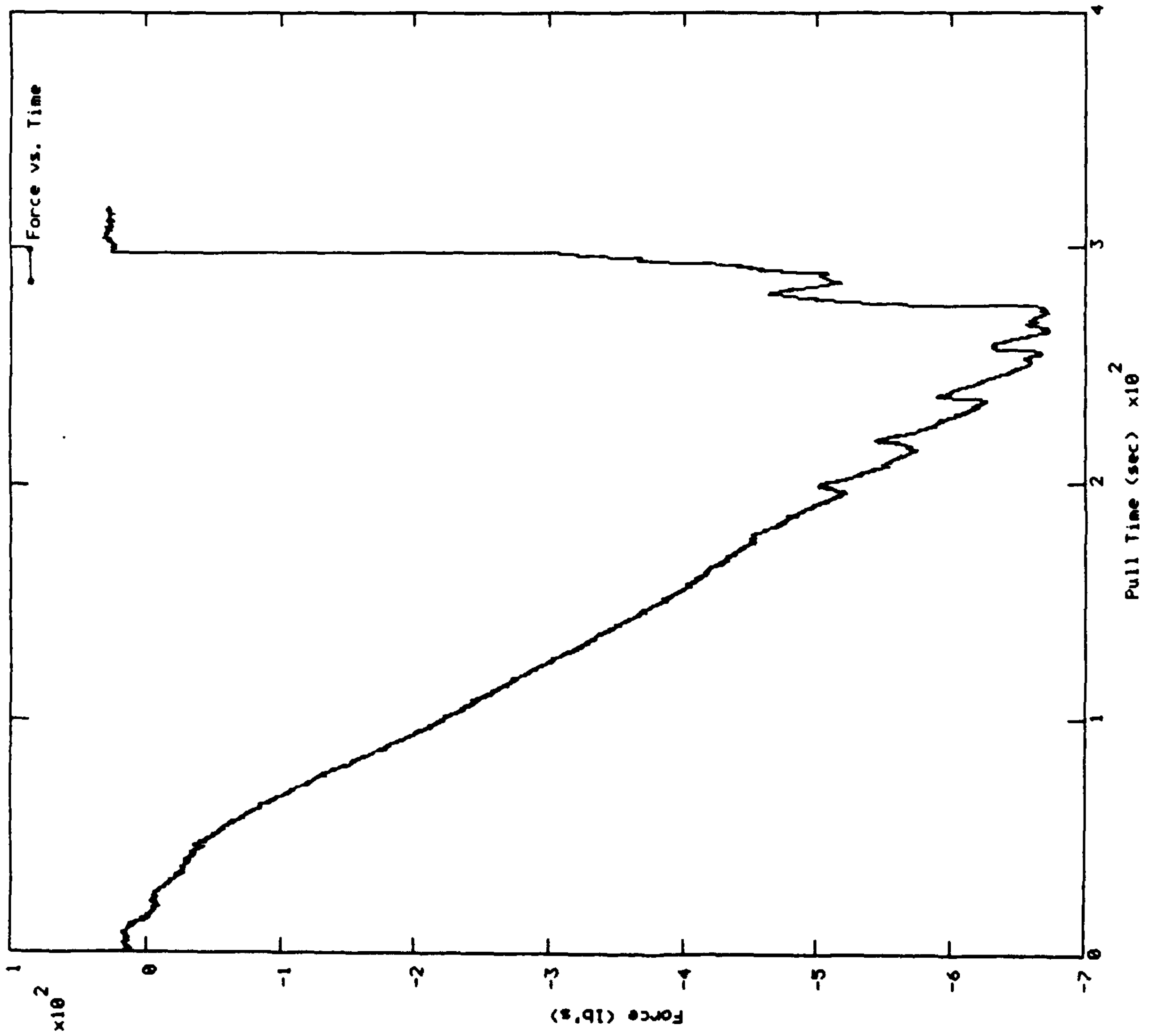

FIGURE 10. MOMENT PULL PRE-TEST

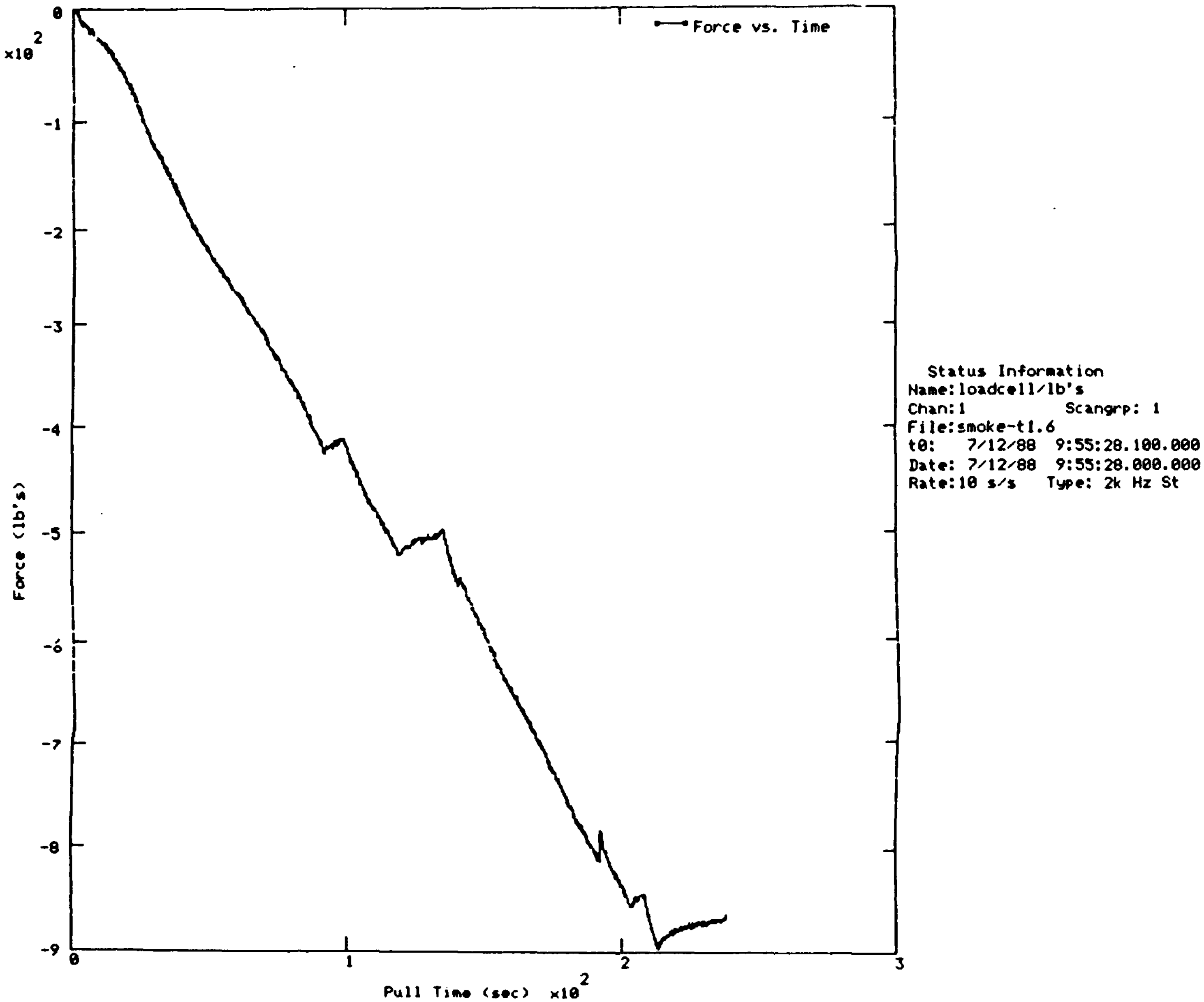

FIGURE 11. MOMENT PULL TEST (ACTUAL)

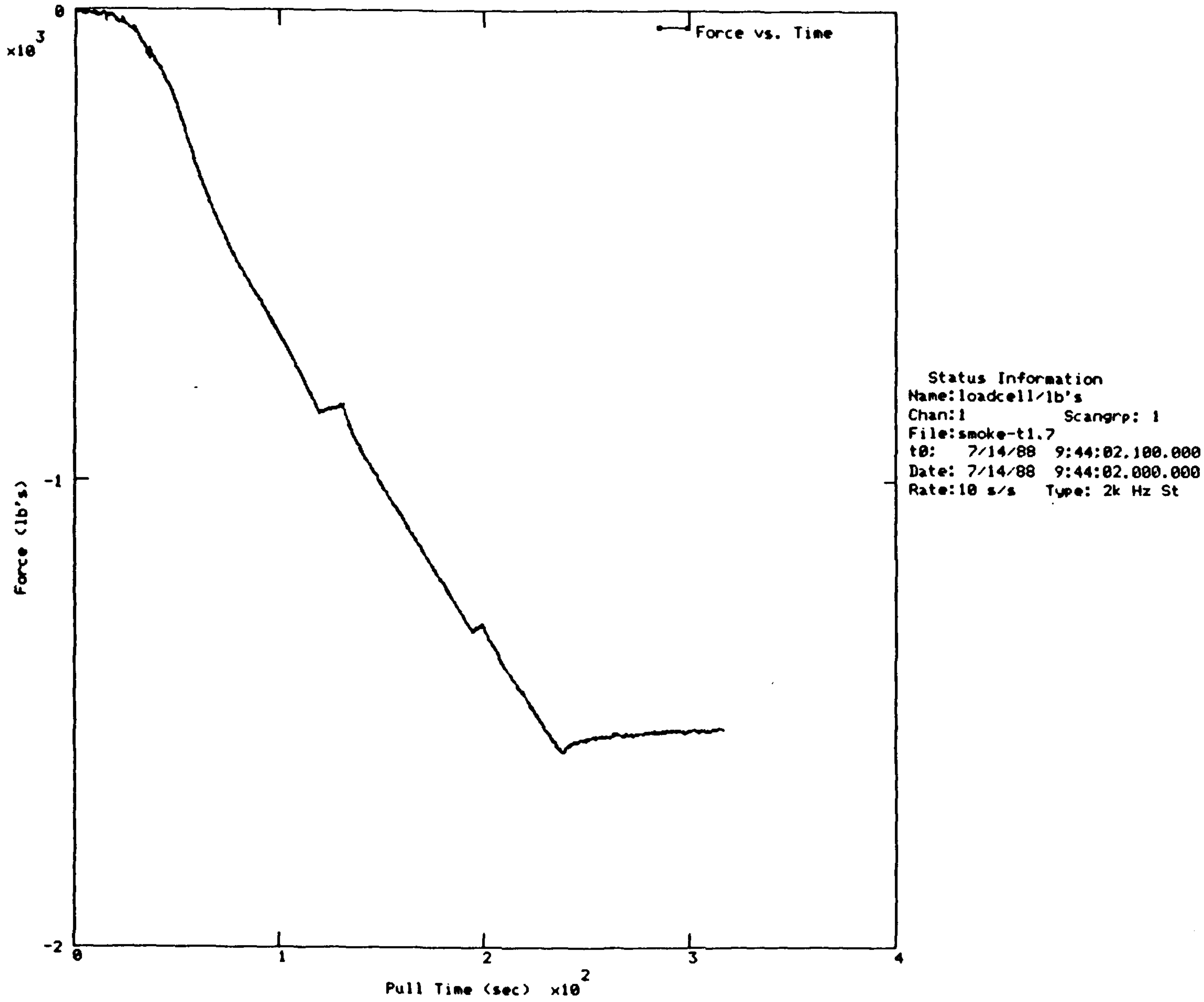

FIGURE 12. NORMAL PULL TEST

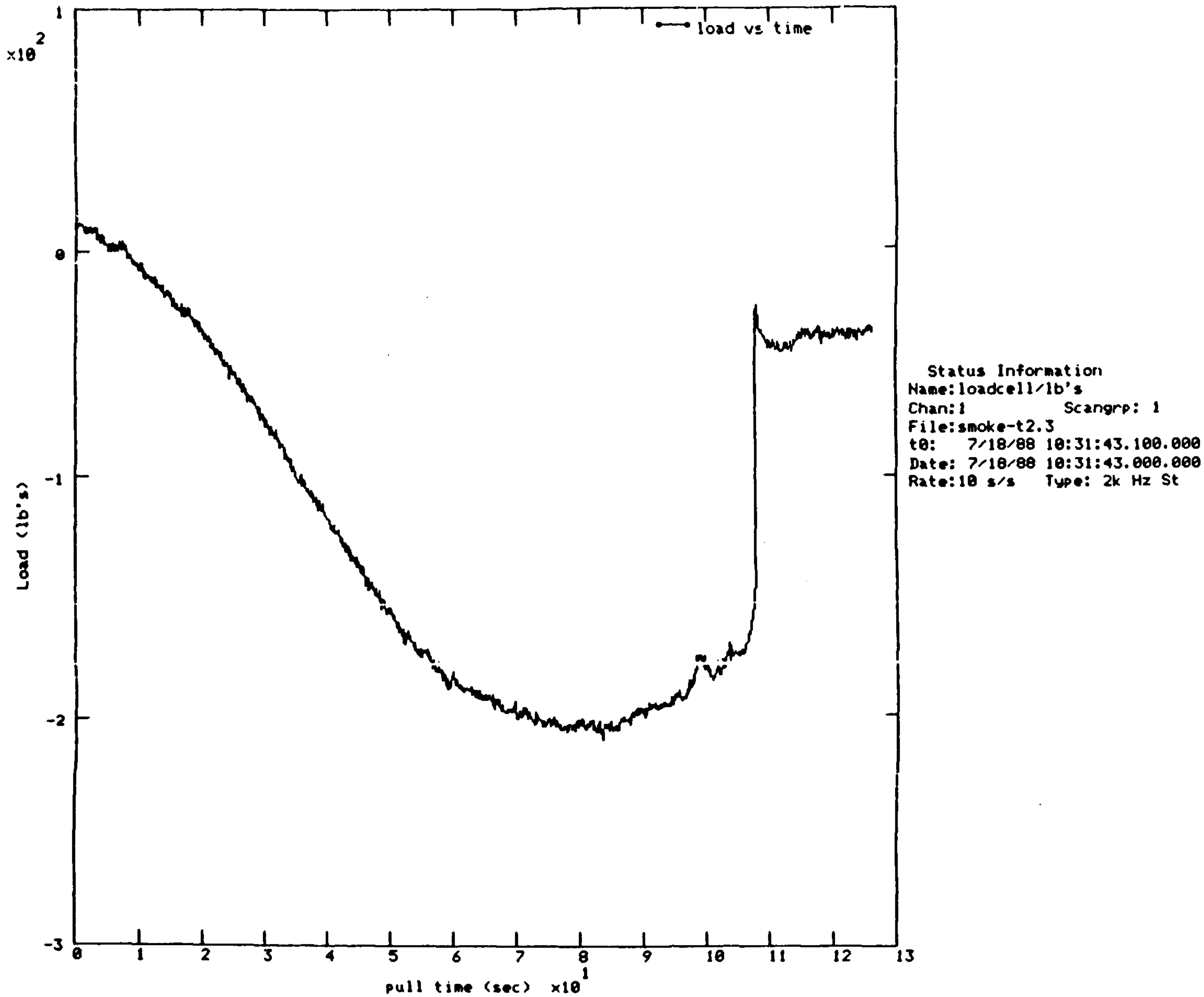

FIGURE 13. SINGLE CLIP PULL TEST NO. 1

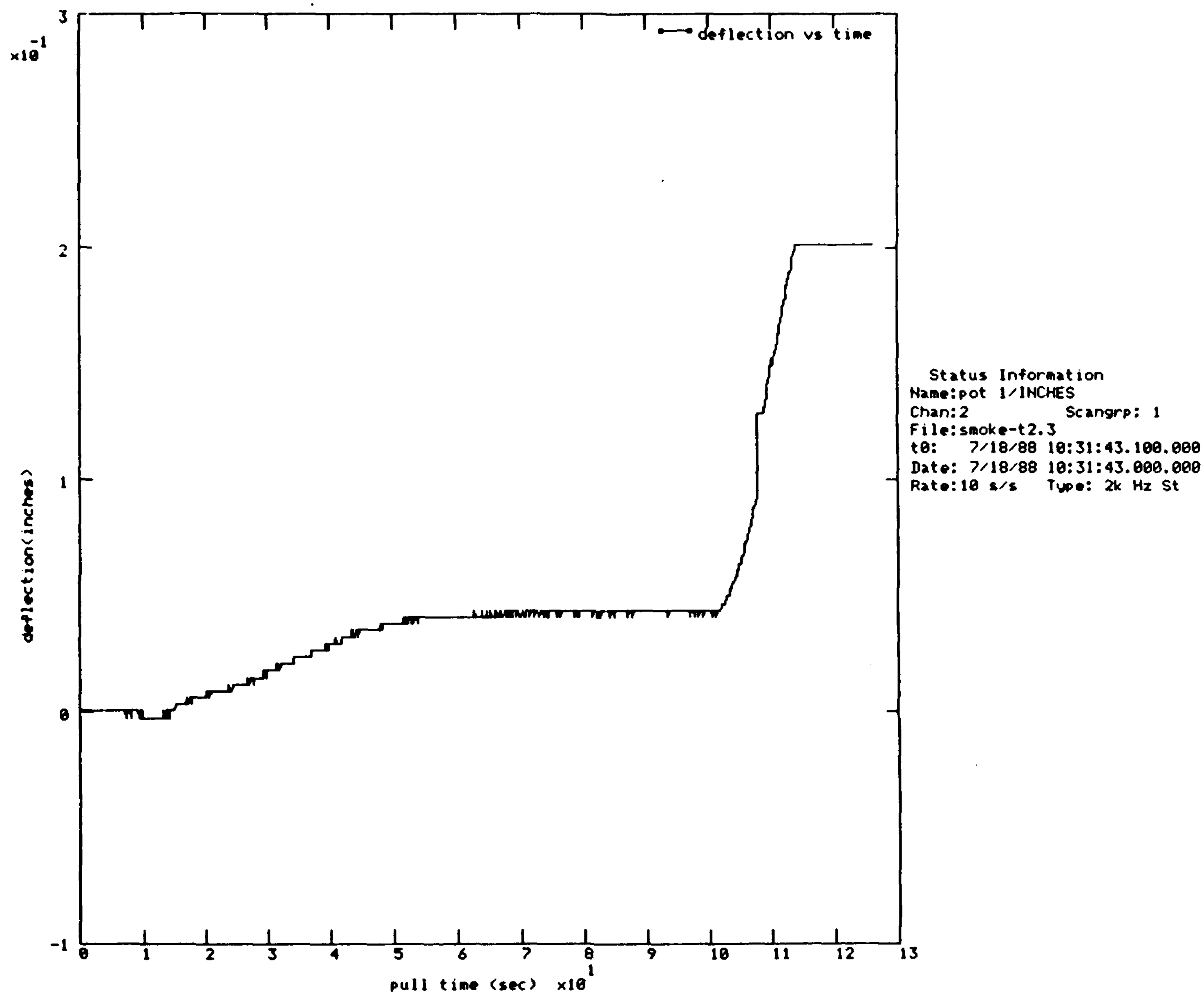

FIGURE 14. SINGLE CLIP PULL TEST NO. 2